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Public Infrastructure Disparities and the Microbiological and Chemical Safety of Drinking and Surface Water Supplies in a Community Bordering a Landfill

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Abstract

The historically African-American Rogers-Eubanks community straddles unincorporated boundaries of two municipalities in Orange County, North Carolina, and predates a regional landfill sited along its border in 1972. Community members from the Rogers-Eubanks Neighborhood Association (RENA), concerned about deterioration of private wells and septic systems and a lack of public drinking water and sewer services, implemented a community-driven research partnership with university scientists and community-based organizations to investigate water and sewer infrastructure disparities and the safety of drinking and surface water supplies. RENA drafted memoranda of agreement with partners and trained community monitors to collect data (inventory households, map water and sewer infrastructure, administer household water and sewer infrastructure surveys, and collect drinking and surface water samples). Respondents to the surveys reported pervasive signs of well vulnerability (100%) and septic system failure (68%). Each 100-m increase in distance from the landfill was associated with a 600 most probable number/100 mL decrease in enterococci concentrations in surface water (95% confidence interval

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= −1106, −93). Pervasive private household water and sewer infrastructure failures and poor water quality were identified in this community bordering a regional landfill, providing evidence of a need for improved water and sanitation services.

Introduction

The disproportionate location of environmental hazards in low-income communities and communities of color is often referred to as environmental injustice (Bullard, 1994; Bullard & Johnson, 2000). This may occur due to specific targeting, or it may be a consequence of historical land use patterns, land prices, or other structural factors arising out of inequalities of race and class (Morello-Frosch Pastor, Porras, & Sadd, 2002; Norton et al., 2007; Wilson, Howell, Wing, & Sobsey, 2002; Wing, Cole, & Grant, 2000). Communities near waste disposal sites or industries that release harmful pollutants or other environmental hazards usually lack the financial resources and institutional connections to conduct research into sources and levels of contamination. It can therefore be difficult to improve understanding of the extent to which low-income communities and communities of color may be disproportionately affected. Such research may help strengthen community organizing efforts and actions to encourage policy change and compliance with public health standards. Although partnerships with researchers can help communities gain access to research and build capacity, the interests of relatively privileged research institutions as well as the career interests of researchers may conflict with the needs of communities facing environmental injustices. This potential for conflict has led to the development of principles to help communities prevent harm and maximize potential for research to improve community welfare (Heaney et al., 2011; Heaney, Wilson, & Wilson, 2007; Israel, Eng, Schulz, Parker, & Satcher, 2005; Minkler, Vasquez, Tajik, & Petersen, 2008; O’Fallon & Dearry, 2002; Parker et al., 2003; Wilson, Bumpass, Wilson, & Snipes, 2008).

Residents of the historically African-American Rogers-Eubanks community located in Orange County, North Carolina, which borders the Orange County regional land-fill, have expressed concerns about a lack of basic amenities including public services such as regulated public drinking water and sewer service; storm water management; paved roads and sidewalks; community lighting; curbside solid waste collection; and emergency medical, fire, and police protection services (Campbell, 2007). Since 1972, Rogers-Eubanks community residents have requested connections to regulated public water and sewer services as well as assessments of the vulnerability of private wells, the failure of onsite septic systems, and the microbiological and chemical safety of drinking and surface water supplies in their community. The objective of our study was to investigate the lack of regulated public drinking water and sewer services and to assess the microbiological and chemical safety of household drinking water and surface water supplies following community-driven research methods (Heaney et al., 2007, 2011).

Methods

Below, we discuss the procedures to map water and sewer infrastructure disparities, inventory households, assess the prevalence of vulnerability and failure characteristics of household water and sewer infrastructure, evaluate the microbiological and chemical safety of drinking and surface water supplies, and sustain partnerships between the Rogers-Eubanks Neighborhood Association (RENA) and researchers at the University of North Carolina at Chapel Hill.

Mapping the Rogers-Eubanks Community, the Landfill, and Basic Amenities Disparities

GIS maps were created based on community members' historical knowledge of their community boundaries. Since 1972, RENA community members have served on local government task forces to develop consensus on community benefits for hosting the regional landfill and to define a boundary area of the predominantly African-American community for enhancement-planning purposes (most task forces defined community boundaries to facilitate cost estimation to provide services to RENA community members). The "Rogers Road Historic Area" was created and maps were produced. These task force maps, GIS data files, and residents' knowledge were combined to map tax parcels and regulated public drinking water and sewer mains (as of November 2007) in the Rogers-Eubanks community. U.S. Census data (from 2000) on percentage African-American at the block level (Census blocks 1000, 1001, and 2020) were used to depict the racial composition of census blocks that bisect the community compared to census blocks surrounding the community. Property value data (from April 2007) were obtained from Orange County, North Carolina, tax parcel records. GIS maps were created using ArcMap.

Survey of Household Water and Sewer Infrastructure Survey

Since 1972, residents of the Rogers-Eubanks community have searched public records, organized residents, and distributed petitions to investigate water and sewer infrastructure concerns. Rogers-Eubanks community residents formed a partnership with scientists at the University of North Carolina at Chapel Hill (UNC) and student members of the Daniel A. Okun chapter of Engineers Without Borders (EWB). Community residents also partnered with the community-based organizations North Carolina Environmental Justice Network (NCEJN) and the West End Revitalization Association (WERA) to seek guidance to establish RENA, a 501c3 organization.

To inform recruitment planning, RENA and its partners inventoried households by reviewing an August 2008 list of tax parcels located in the Rogers-Eubanks community as compiled by the local county water and sewer authority. RENA tabulated the number of parcels with and without connections to regulated public water and sewer service, cross-referencing this list with community members' input to exclude vacant parcels and households recently built by Habitat for Humanity. RENA members performed outreach to households on the inventory list by going door-to-door and calling residents to inform them about the study partnership and survey and by inviting residents to attend community meetings describing the study. Study brochures were distributed door-to-door and in person at community meetings held at a local church. RENA community members administered surveys to households that responded with interest.

Household survey questions were adapted from a survey developed by WERA, a community-based partner of RENA (Heaney et al., 2011), and covered information on household demographics such as race/ethnicity, age, average annual income, number of household occupants, rental/ownership status, age of the home, and length of residence within home. Guidelines of the World Health Organization (WHO, 1994), the North Carolina Department of Environment and Natural Resources (NCDENR, 2012), and Orange County Health Department's Division of Environmental Health Services (OCHD, 2008) were used to evaluate signs of the following:

1. Well vulnerability, defined as reports of one or more of the following: failure of the well pump; well water has a cloudiness, tastes bad, or smells bad; and history of disinfection of the well with chlorine.
2. Septic system failure, defined as reports of one or more of the following: septic tank pumping frequency of at least once a year; septic discharge making the yard wet during nonrainfall periods; and septic system backup into the home.

The household survey also included questions designed to assess residents' willingness to connect to municipal services, ability to pay a monthly water and sewer bill, willingness to sign a petition to be annexed by nearby towns, influences on decisions related to annexation (e.g., connection to water and sewer services, access to community development block grant [CDBG] funds, right to vote in town elections, voice in zoning of property), and willingness to sign a petition to create a neighborhood conservation district as a strategy to ease possible tax increases from annexation.

Drinking and Surface Water Sample Collection and Analysis

Teams of RENA community monitors (CMs), UNC scientists, and EWB members were trained in the aseptic method of water sample collection as described in the 20th edition of the American Public Health Association's (APHA's) *Standard Methods for the Examination of Water and Wastewater* (APHA, 1998). Drinking water samples were drawn from an indoor faucet, outdoor spigot, or from the well pump spigot after running the water for three minutes. Drinking water samples were collected at households using private wells and those using regulated public water service. A surface water sample collection dry run was completed in May 2009 and weekly surface water samples were collected between June and July 2009 at varying distances from the landfill. GPS coordinates were recorded (latitude and longitude) for each surface water sampling location. Each water sample was assigned a unique alphanumeric code before transport at 4°C to the laboratory for analysis.

Physical, Microbiological, and Chemical Measurements

Turbidity was measured in nephelometric turbidity units (NTU) using the Hach 2100N turbidimeter. Fecal coliforms and *E. coli* were measured using the Colilert IDEXX Quanti-Tray most probable number (MPN) assay. Enterococci were enumerated using the Enterolert IDEXX Quanti-Tray MPN assay. The North Carolina Division of Water Quality laboratory performed aluminum, arsenic, barium, cadmium, copper, chromium, nickel, lead, selenium, silver, and volatile organic compounds analyses of water samples following standard methods (U.S. Environmental Protection Agency [U.S. EPA], 1996a, 2006a, 2007a, 2007b). A state-certified commercial laboratory performed total organic carbon analyses of surface water samples following standard methods (APHA, 1998). The North Carolina Department of Agriculture and Consumer Services (NCDACS) laboratory performed analyses of ammonia, chlorine, iron, magnesium, manganese, nitrate, pH, phosphorus, potassium, total alkalinity, zinc, and hardness in drinking and surface waters in accordance with NCDENR specifications and methods for routine soil and solutions reports (NCDACS, 2012; NCDENR, 2005a, 2005b).

Statistical Analysis

Two-sample exact tests were used to evaluate differences in mean turbidity (NTU) and median fecal indicator bacteria (FIB) (MPN/100 mL) levels in private well water compared with public water samples (Stokes, Davis, & Koch, 2001). Binary variables, based on U.S. Environmental Protection Agency (U.S. EPA) national primary drinking water standards maximum contaminant limits (MCLs) set by the Safe Drinking Water Act Amendments of 1996 (U.S. EPA, 1996b) and NCDENR groundwater quality standards (NCDENR, 2005a), were created for turbidity (>1.0 vs. ≤1 NTU), fecal coliforms (≥vs. <1 MPN/100 mL), and *E. coli* (≥1 vs. <1 MPN/100 mL). Although no drinking water quality guideline exists for enterococci, a binary variable was created for enterococci (≥1 vs. <1 MPN/100 mL). A binary index variable was created to reflect when samples exceeded one or more of the drinking water quality standard MCLs for turbidity, fecal coliforms, or *E. coli*. Wilcoxon and Fisher's exact tests (Stokes et al., 2001) were used to evaluate the statistical significance of associations (two-tailed tests) between each binary drinking water fecal indicator variable (turbidity, fecal coliforms, *E. coli*, and enterococci) and binary variables for drinking water type (e.g., private well vs. public water) and septic system failure (i.e., yes vs. no), respectively (Stokes et al., 2001). Randomization was not used in the study design, therefore reported *p*-values should not be interpreted as reflecting the probability that the results would be observed by chance under the null hypothesis that no difference exists between the groups being compared.

Binary variables based on U.S. EPA and NCDENR recreational freshwater quality criteria were created to assess the frequency with which microbiological and chemical criteria and standards were exceeded in weekly surface water samples. Fixed effects linear regression models, conditioned on sampling location, were used to evaluate the association between weekly measures of concentrations of surface water quality parameters with increasing distance from the landfill (Allison, 2005). Statistical analyses were completed using SAS version 9.

Results

Mapping Regulated Public Water and Sewer Services in the Rogers-Eubanks Community

Figure 1 shows the boundary of the Rogers Road Historic Area (in a solid black line), which is the area of the Rogers-Eubanks community delineated by local governments for enhancement planning purposes. Regulated public water and sewer mains are depicted as Orange Water and Sewer Authority (OWASA) water and sewer mains, respectively. Figure 1 shows a large network of regulated public drinking water and sewer mains surrounding the Rogers Road Historic Area, with some extensions bisecting the community. The OWASA water mains that extend into the Historic Rogers Road Area south of the Orange County regional landfill (Figures 1 and 2) have provided some households access; however, service connections remain out of reach for some Rogers-Eubanks community members. Census data on blocks 1000 (60% African-American) and 2020 (64% African-American) cover the majority of the area of the Rogers Road Historic Area. Census block 1001 (10% African-American) bisects the western area of the Rogers Road Historic Area (Figure 1) and is weighted disproportionately by a large non-African-American population in new high-density developments at the southern area of census block 1001. The Rogers Road Historic Area's proximity to the Orange County regional landfill is also depicted (Figure 1). Figure 2 displays total tax parcel value data from April 2007, illustrating a geographic pattern of depressed total tax parcel value that encompasses the Rogers Road Historic Area.

Survey of Household Water and Sewer Infrastructure

Household Recruitment and Demographic Characteristics—RENA formed 11 partnerships with university, community-based, and other service organizations, and trained six CMs to collect environmental data. RENA identified 73 households located in the historic African-American Rogers-Eubanks community. Of the 73 identified households, 38 (52%) responded positively to RENA's outreach activities. Of these 38 households, a total of 27 respondents (71%) completed a household survey, with one adult household member providing responses for additional household members. A total of 58 individuals lived in the 27 households surveyed. Twenty-six (96%) respondents reported African-American race/ethnicity and one (4%) reported Caucasian race. Just over one-third of the respondents were above the age of 65. Thirteen respondents reported an annual household income of <$30,000 and 23 reported two or more people living in the household. Six respondents (out of 27) reported that they had a job or occupation, which included keeping house or going to school, as well as working for pay or profit. Forty-one percent of the homes were built 30 or more years ago and nearly half of respondents reported living in their home for 30 years or longer (Table 1).

Vulnerability of Household Wells and Failure of Private Household Septic Systems—Seventeen households (52%) reported having an operating private well, of which seven reported using a private well as their primary drinking water source. The median year of well construction was 1962 (with the oldest constructed in 1949 and the most recent in 2005). Signs of well vulnerability were common and included failure of the well pump (14 of 17); a cloudiness, bad taste, or bad smell of well water (14 of 17); and a history of disinfection of the well with chlorine or another chemical (6 of 17). All 17 household well owners surveyed reported one or more of these three signs of well vulnerability (Table 2).

Twenty-two households (78%) reported having a private onsite septic system. The median year of septic system construction was 1971 (with the oldest constructed in 1926 and the most recent in 2008). Signs of septic system failure were common. Five households reported a septic tank pumping frequency of at least once a year, two reported septic discharge making the yard wet, six reported septic backup into the home, and 19 reported septic system malodor. Fifteen of 22 septic system users surveyed reported one or more signs of septic system failure. Of the 15 households with private septic systems and operating wells, 10 (67%) had one or more signs of well vulnerability and one or more signs of septic system failure (Table 2).

Willingness to Connect to Water and Sewer Services—Survey respondents reported that if a connection could be provided to them free of charge, they would be willing to connect to the following: public water only (1/28); public sewer only (5/28); both (18/28); neither (2/28), or didn't know whether they would be willing to be connected (1/28). Just over half (15/27) of respondents said that if they were connected, they could afford to pay a monthly water and sewer bill. Just under half of respondents (13/26) said that they would be willing to sign a petition to be annexed into town limits and 6/26 said they didn't know if they would be willing. Reasons respondents provided as influencing their decision about annexation included possibility of future connection to regulated public water and sewer services (8/13); access to CDBG funding for home repairs such as winterizing (10/13); right to vote in town elections (10/13); and voice in zoning of property (11/13). Eleven of 25 respondents reported needing urgent home repairs including plumbing (4/11), roof (4/11), windows/doors/winterizing (4/11), ceiling (3/11), floors (2/11), electrical (2/11), and disability ramp (2/11). Eight of 27 respondents reported that they would be willing to sign a petition to create a neighborhood conservation district as a strategy to ease possible tax increases as a result of annexation, but over half (15/27) said they did not know whether or not they would be willing to sign such a petition.

Microbiological Safety of Household Drinking Water

Drinking water samples were collected from 20 households in the Rogers-Eubanks community: 12 households with private wells and 8 households with a regulated public drinking water supply. The FIB fecal coliforms, *E. coli*, and enterococci were detected in private wells, but not in regulated public drinking water (Table 3). The presence of fecal coliforms, *E. coli*, and enterococci was observed in 5/12, 1/12, and 1/12 private wells, respectively (Table 3). Mean turbidity of private well water samples was 28 NTU versus 0.7 NTU for public water ($p = .0005$) (Table 3). Of the 12 wells sampled, 8 wells had turbidity levels higher than standards set for public water utilities (1.0 NTU) (U.S. EPA, 2006b). Using a binary index variable of MCL violations for turbidity, fecal coliforms, and *E. coli*, all 12 private well water samples exceeded at least one or more national primary drinking water standards (U.S. EPA, 2006b), compared with only one of the regulated public drinking water samples (turbidity MCL violation only) ($p = .0001$). We did not observe evidence that microbiological and turbidity drinking water measures were associated with household septic system failure (data not shown).

Chemical Safety of Household Drinking Water

Methyltert-butylether (MTBE) (0.7 μg/L), trichloroethene (2 μg/L), 2,6-di-tert-butyl-quinone (2.3 μg/L), and 1,2-dichloropropane (2 μg/L) were detected in one private well. Another private well had measureable amounts of MTBE (2.2 μg/L) and one other well had measureable amounts of 1,1-dichloroethane (0.6 μg/L) (Table 3). Levels of MTBE, trichloroethene, 2,6-di-tert-butylquinone, 1,2-dichloropropane, and 1,1-dichloroethane were all below federal (U.S. EPA, 2006b) and North Carolina (NCDENR, 2005a) drinking water quality standards.

Nitrate levels in wells were below the federal (U.S. EPA, 2006b) and North Carolina groundwater standard of 10 parts per million (ppm) (NCDENR, 2005a). Mean nitrate in private wells was higher than in regulated public water supplies ($p = .0024$). The highest nitrate level in a private well was 4.2 ppm and in regulated public water was 0.5 ppm. Mean ammonia in private wells was also higher than in regulated public water supplies ($p = .00004$) (Table 3).

Levels of aluminum, barium, cadmium, copper, nickel, and zinc were detected in private wells within current regulatory standards (U.S. EPA, 2006b). Five of 12 wells were above the federal recommended drinking water limit of 0.3 mg/L for iron (U.S. EPA, 2006b) and mean iron was higher in private wells than in regulated public water supplies ($p = .0381$). One private well (0.065 mg/L) exceeded the federal recommended drinking water limit of 0.015 mg/L for lead (Table 3) (U.S. EPA, 2006b). Five of 12 wells were above the federal recommended drinking water limit of 0.05 mg/L for manganese (U.S. EPA, 2006b). One public water sample (2.7 mg/L) exceeded the federal recommended drinking water limit of 1.3 mg/L for copper (U.S. EPA, 2006b).

Chlorine was observed in all private well and regulated public water supplies at concentrations greater than 4.0 mg/L, the maximum residual disinfectant level set by U.S. EPA (2006b). Higher mean chlorine concentrations were observed, however, in regulated public water supplies compared with private wells ($p = .0007$). Disinfection by-products in the total trihalomethane group were detected more frequently and at higher mean concentrations in regulated public drinking water compared with private well water. For example, mean dibromochloromethane ($p = .0361$) and chloroform ($p = .0361$) concentrations were higher in regulated public drinking water supplies compared with private wells. Mean pH was lower in private wells compared with regulated public water supplies ($p = .00004$). Of the 12 private wells sampled, 11 were below the recommended drinking water limit of 6.5 pH units, whereas none of the public water samples fell below this pH limit ($p = .0002$) (Table 3) (U.S. EPA, 2006b).

Microbial Safety of Recreational Surface Water Supplies

Recreational surface water supplies exceeded the recommended federal guideline for fecal coliforms (200 MPN/100 mL) in 40/40 samples, *E. coli* (126 MPN/100 mL) in 21/50 samples, and enterococci (33 MPN/100 mL) in 43/50 samples. Twenty-one of 40, 8/50, and 11/50 surface water samples exceeded the assay upper detection limit (>2,420 MPN/100 mL) for fecal coliform, *E. coli*, and enterococci, respectively (Table 4). Twenty-nine of 50 samples exceeded the NCDENR-recommended turbidity guideline of 50 NTU for protection of freshwater aquatic life and 45/50 samples exceeded the NCDENR recommended guideline of 10 NTU for trout fishing waters (NCDENR, 2007).

Chemical Safety of Recreational Surface Water Supplies

Levels of nitrate and ammonia were low in all surface water samples (Table 4). pH was below 6.0 in 26/40 samples, which is the NCDENR recommended lower limit for protection of freshwater aquatic life (NCDENR, 2007). The NCDENR recommended levels for protection of freshwater aquatic life (NCDENR, 2007) were exceeded for aluminum (50 μg/L) in 2/40 samples, copper (7 μg/L) in 4/40 samples, iron (1 ppm) in 38/40 samples, and manganese (200 μg/L) in 27/40 samples. Total organic carbon was detected in 50/50 surface water samples (range = 2.5–83 mg/L). Disinfection byproducts and other volatile organics were detected at low levels (Table 4).

Association Between Distance From Landfill and Surface Water Quality

A 100-m increase in distance from the land-fill was associated with a 600 MPN/100 mL decrease in average enterococci concentrations in surface water (95% confidence interval = −1106, −93) (Table 5). Concentrations of surface water contaminants generally decreased with increasing distance from the landfill. Associations between distance from the landfill and concentrations of other contaminants were not as strong, however, as the association observed for enterococci (Table 5).

Discussion

The results of our study suggest that racial and socioeconomic disparities exist in the geographic distribution of regulated public drinking water and sewer services (Figures 1 and 2) and that, among households surveyed in the Rogers-Eubanks community, problems exist with drinking water and sewer infrastructure, housing conditions, and the microbiological and physical-chemical safety of private well water and surface water supplies. Through this community-driven research approach (Heaney et al., 2007, 2011) Rogers-Eubanks community members empowered themselves to establish a 501c3 community-based organization (i.e., RENA), used memoranda of understanding to prioritize research partnerships, and developed organizational capacity to support environmental data collection. GIS maps and household survey data revealed service-extension and connection disparities in this predominantly African-American community. Although regulated public drinking water and sewer mains extend to portions of the historic Rogers-Eubanks community, some African-American households cannot afford construction and tap-on costs associated with lateral lines to connect to regulated public drinking water and sewer mains. Local governments have not funded lateral line connections for all households regardless of income.

RENA’s household survey data collection, involving training community monitors to distribute study brochures, make door-to-door visits and phone calls, and organize community meetings, resulted in slightly more than half of the households in the historic Rogers-Eubanks community responding positively to outreach activities, and nearly three-quarters of those households responding to the survey. The strength of the household survey results is not necessarily in their representativeness of, or generalizability to, the broader Rogers-Eubanks community; rather, they demonstrate that some Rogers-Eubanks households do indeed have problems with drinking water and sewer infrastructure, housing conditions, and compliance with microbiological and chemical water quality criteria and standards.

While the sample was small (N = 27), all 17 households with operating private wells reported one or more signs of vulnerability and 15 of 22 (68%) households with private septic systems reported one or more signs of failure. Comparison data from a countywide survey of 1,333 onsite septic systems in Orange County, North Carolina, in 1980 showed an 11% prevalence of failure (Grayson, Olive, & Steinbeck, 1982).

Turbidity, or the amount of suspended solids in water, was higher in private well water samples than in regulated public drinking water samples. This is important because pathogenic bacteria and viruses can attach to suspended solids and solids can also interfere with well disinfection techniques, leading to an increased risk of gastrointestinal illness (Egorov, Naumova, Tereschenko, Kislitsin, & Ford, 2003; Morris, Naumova, Levin, & Munasinghe, 1996; Schwartz & Levin, 1999; Schwartz, Levin, & Goldstein, 2000; Uhlmann et al., 2009; U.S. Geological Survey, 2009). Fecal coliforms, *E. coli*, and enterococci were detected in private well water samples (at concentrations up to 1,553 MPN/100 mL), but not in regulated public drinking water samples. These FIB suggest the presence of fecal contamination and although research has shown these FIB can occur at high concentrations in landfill leachate and groundwater (Belle, Genevois, Mudry, & Aleya, 2008; Fantuzzi et al., 2003; Li, Li, Luo, & Li, 2008), numerous other sources of these FIB exist in the environment (Borrego & Figueras, 1997; Field & Samadpour, 2007). FIB presence in drinking water has been associated with pathogenic microorganisms and gastrointestinal illness outbreaks (Liang et al., 2006). U.S. EPA has established national primary drinking water standards (U.S. EPA, 1996b, 1998b, 2006b) for public water systems based on turbidity, fecal coliforms, and *E. coli*, and a higher prevalence of turbidity MCL violations was observed in private well water samples than in public drinking water samples. Failure of private septic systems did not appear to be related to measures of drinking water quality, although these results should be interpreted with caution due to the small sample size (data not shown).

Inorganic and volatile organic chemicals in drinking and surface water supplies sampled were generally detected below recommended levels for protection of human health and freshwater aquatic life (NCDENR, 2005, 2007; U.S. EPA, 1986, 2006b). The presence of MTBE, trichloroethene, and other volatile organic chemicals in well water in the Rogers-Eubanks community, however, suggests that further investigation of groundwater quality and provision of improved water sources may be advisable.

We observed an association between increasing distance from the landfill and decreasing levels of enterococci in surface waters sampled. The sources of FIB in surface waters are diverse, however, and can also include failing septic systems, runoff, and domestic and wild animals. Although rainfall can influence levels of FIB in surface waters, little variability exists in precipitation across the small sampling area of the Rogers-Eubanks community. We did not aim to evaluate specific sources of contamination but rather to assess the general microbiological and chemical quality of surface water supplies sampled in the Rogers-Eubanks community. Tests of soil at the junction of two stormwater outfall pipes encompassing drainage to surface water downstream of an unlined construction and demolition land-fill and a lined municipal solid waste landfill in the Rogers-Eubanks community revealed the presence of arsenic, chromium, lead, nickel, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzoic acid, chrysene, fluoranthene, indeno(1,2,3,-cd)pyrene, and pyrene (data not shown).

The lack of basic amenities is emerging as a national issue in low-income communities of color and has been tied to historical and ongoing institutional racism (Johnson, 2008; Smyth, 2008; Wilson, 2009; Wilson, Bumpass et al., 2008). Community-based organizations across the southern U.S. often face substantial challenges for data collection to assess the extent of problems with private water and sewer infrastructure services. Marginalized and underserved residents of color often harbor mistrust of state environmental protection agencies, local health departments, elected officials, and academic researchers attempting to investigate private household drinking water and sewer infrastructure problems (Wilson, Bumpass et al., 2008). Residents may fear condemnation of their property if violations are discovered. This presents substantial barriers to achieving high participation in research to characterize the extent of drinking water and sewer infrastructure disparities in such marginalized and underserved communities (Wilson, Bumpass et al., 2008) and could lead to underestimation of the prevalence of failed systems and the existence of problems with water quality in these communities.

Conclusion

The community-driven research partnership between grassroots RENA community members and academic researchers reduced some residents' mistrust of the research process, led to participation by a population not often trusting of scientific research, and fostered collection of environmental data in a community bordering a landfill and lacking basic amenities. Data collected by the partnership revealed a disconnect between community drinking water and sewer infrastructure conditions and local public health compliance, enforcement, and assurance actions, and fostered local, state, and national policy and legal discussions about environmental justice concerns in the Rogers-Eubanks community (Campbell, 2007; Heaney et al., 2007; Wilson, Bumpass et al., 2008; Wilson, Heaney, Wilson, & Cooper, 2007).

The results of our study contribute further evidence to an understudied and emerging national environmental justice issue—the lack of basic amenities (Wilson, Cooper, Heaney, & Wilson, 2008). Effective interventions exist at the historical root of the public health movement (improving water and sanitation services) (Cutler & Miller, 2005; Kjellstrom, 2007; Ringen, 1979). Substantial institutional barriers to extending safe and adequate services to low-income communities of color endure, however, at the local level across the U.S. and have been characterized by some as environmental racism (Johnson, 2008; Smyth, 2008; Wilson, Bumpass et al., 2008) due to inequities in local planning and zoning practices (Maantay, 2001; Maantay, 2002; Wilson, Cooper et al., 2008; Wilson, Hutson, & Mujahid, 2009). Replication of this community-driven research partnership approach in similarly marginalized and underserved low-income communities of color could help identify problems with and improve the microbiological and chemical safety of drinking and surface water supplies and advance a national popular movement for a right to basic amenities.

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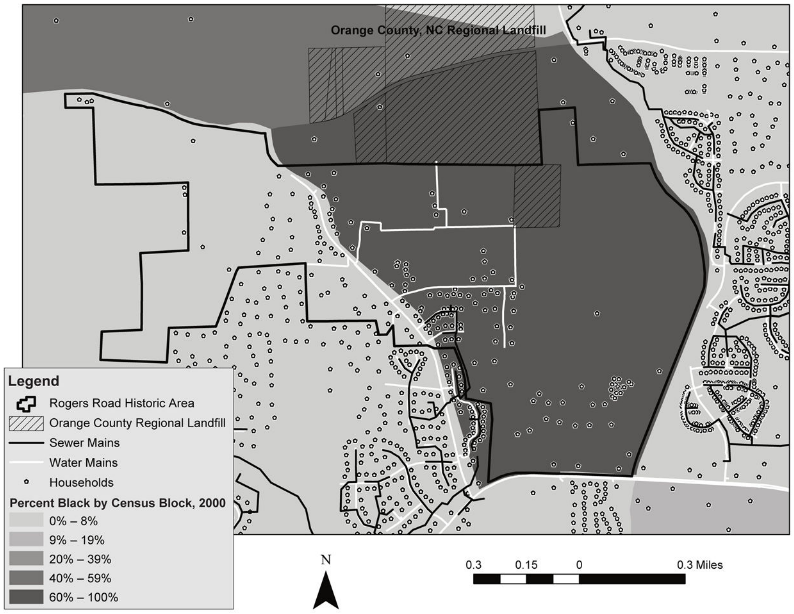

FIGURE 1.

Distribution of Regulated Public Water and Sewer Mains and Percentage African-American by Census Block (2000 U.S. Census) Within and Outside of the Historic Rogers-Eubanks Community

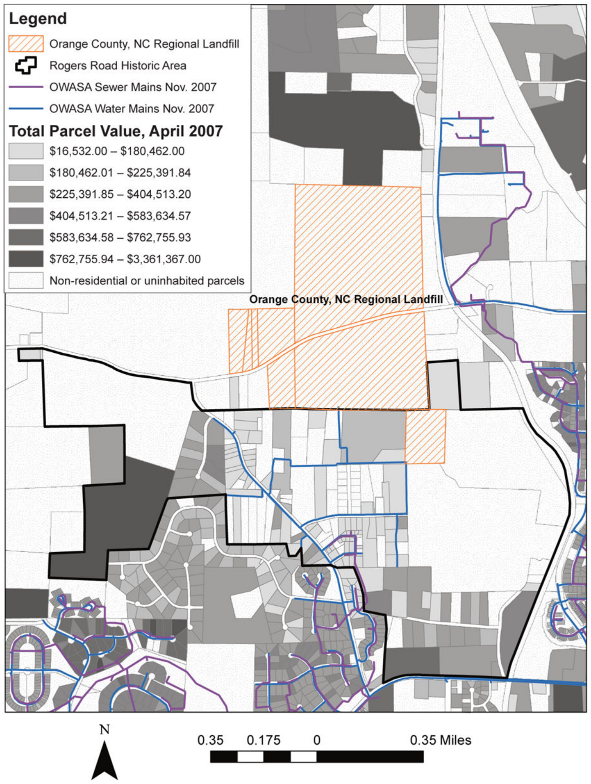

FIGURE 2.

Total Tax Parcel Value Within and Surrounding the Orange County Regional Landfill and Historic Roger-Eubanks Community

TABLE 1

Demographic Characteristics of Households Surveyed in a Community Bordering a Regional Landfill

Characteristic	**#**	**%**
Households in the Rogers-Eubanks community	73	100
Households responding to outreach	38	52
Households responding to survey	27	71
Race/ethnicity		
Caucasian	1	4
African-American	26	96
Age group (yrs.)		
18–<35	0	0
35–<45	1	4
45–<55	8	31
55–<65	7	27
≥65	10	38
Not given	1	4
Number of household occupants		
1	5	21
2	10	42
3	4	17
4	4	17
5	5	4
Not given	3	11
Annual household income		
<$20,000	6	29
$20,000–<$30,000	7	33
$30,000–<$40,000	5	24
$40,000–<$50,000	1	5
≥$50,000	0	0
Don’t know	2	10
Not given	6	22
Number of years occupant lived in the household		
<1	1	4
2–<5	3	12
5–<10	2	8
10–<20	5	19
20–<30	2	8
≥30	13	50
Not given	1	4
Homeownership status		

Characteristic	**#**	**%**
Rent	1	4
Own	26	96

TABLE 2

Drinking Water and Sewage Disposal System Characteristics at Households Surveyed in a Community Bordering a Regional Landfill

Characteristic	**#**	**%**
Household drinking water source (*N* = 27)		
Regulated public water	20	74
Private well	7	26
Households with an operating private well (*N* = 27)		
Yes	17	63
No	9	33
Not given	1	4
Year of well construction (*n* = 17)		
Before 1950	1	6
1950–<1975	6	35
1975–<1995	4	23
1995–present	1	6
Don’t know	1	6
Not given	4	24
History of well pump failure (*n* = 17)		
Yes	14	82
No	1	6
Don’t know	1	6
Not given	1	6
Well water is cloudy, tastes bad, or smells bad (*n* = 17)		
Yes	14	82
No	3	18
History of chemical treatment of well water (*n* = 17)		
No	8	47
Chlorine or other chemical	6	35
Don’t know	3	18
Household wells with one or more signs of vulnerability (*n* = 17)		
Yes	17	100
No	0	0
Household sewage disposal system (*n* = 17)		
Connected to regulated public sewage	5	19
Private septic system	22	81
Year of septic system construction (*n* = 22)		
Before 1930	1	5
1930–<1950	1	5
1950–<1970	7	33

Characteristic	#	%
1970–<1990	4	19
1990–present	6	20
Don’t know	2	10
Not given	1	5
Septic tank pumping frequency (*n* = 22)		
Less than once a year	13	59
At least once a year	5	23
Don’t know	3	14
Not given	1	5
Septic system makes yard wet during nonrainfall periods (*n* = 22)		
Yes	2	9
No	20	91
Septic system backs up into the home (*n* = 22)		
Yes	6	27
No	16	73
Households with one or more signs of septic system failure (*n* = 22)		
Yes	15	68
No	7	32

Note. Vulnerable private household well defined as one or more of the following: history of pump failure; cloudiness, bad taste, or bad smell of water; or history of treatment of well. Private septic system failure defined as one or more of the following: septic tank pumping frequency of at least once a year; septic system makes yard wet during nonrainfall periods; or septic system backs up into the home.

TABLE 3

Microbial and Chemical Contaminants in Private Well Water Versus Public Drinking Water at Households in a Community Bordering a Regional Landfill

Contaminant	Private Well Water			Public Water		
	#	# Pos[a]	Mean (Min, Max)[b]	#	# Pos[a]	Mean (Min, Max)[b]
Turbidity (NTU)	12	8[c]	28 (0.3, 231)**	8	1[c]	0.7 (0.1, 4.7)**
Fecal coliforms (MPN/100 mL)	12	5	23 (0.5, 236)	8	0	–
E. coli (MPN/100 mL)	12	1	1	8	0	–
Enterococci (MPN/100 mL)	12	1	1553	8	0	–
Nitrate (ppm)	12	12	1.1 (0.1, 4.2)*	7	4	0.1 (0, 0.5)*
Ammonia (ppm)	12	12	0.5 (0.4, 0.7)***	7	4	0.2 (0.2, 0.4)***
pH[d]	12	–	5.5 (4.6, 6.8)***	7	–	8.0 (7.8, 8.2)***
Total alkalinity $CaCO_3$ (ppm)	12	12	35 (10, 140)	7	7	45 (25, 110)
Arsenic	12	0	–	7	0	–
Aluminum	12	1	2*	7	3	1296 (0, 8300)*
Barium	12	2	2.5 (0, 28)**	7	7	29 (26, 38)**
Cadmium	12	1	2	7	0	–
Chlorine (mg/L)	12	12	8.8 (4.4, 23.8)**	7	7	18 (16, 20)**
Copper	12	12	90.8 (6.1, 510)	7	7	400 (7.6, 2700)
Iron (mg/L)	12	8	4.0 (0, 36.0)*	7	1	0.3*
Lead	12	2	6.3 (0, 65)	7	1	15
Manganese (ppb)	12	8	99.2 (0, 520)*	7	0	–
Nickel	12	0	–	7	1	20
Selenium	12	0	–	7	0	–
Silver	12	0	–	7	0	–
Zinc	12	12	135 (34, 630)*	7	6	55 (0, 250)*
1,1-Dichloroethane	12	1	0.6	7	0	–
1,2-Dichloropropane	12	1	2	7	0	–

Contaminant	Private Well Water			Public Water		
	#	# Pos[a]	Mean (Min, Max)[b]	#	# Pos[a]	Mean (Min, Max)[b]
2,6-Di-tert-butylquinone	12	1	2.3	7	0	–
Bromodichloromethane	12	0	–	7	2	3 (0, 11)
Bromomethane	12	0	–	7	0	–
Chloroform	12	1	0.17*	7	3	16 (0, 41)*
Chloromethane	12	0	–	7	0	–
Dibromochloromethane	12	0	–	7	3	0.7 (0, 1.9)*
Isopropylalcohol	12	0	–	7	0	–
Methyltert-butylether	12	2	0.2 (0, 2.2)	7	0	–
Trichloroethene	12	1	2	7	0	–

Note. NTU = nephelometric turbidity units; MPN = most probable number; ppm = parts per million; $CaCO_3$ = calcium carbonate; ppb = parts per billion.

[a] Number of samples above the detection threshold unless otherwise noted.

[b] Units are μg/L unless otherwise noted.

[c] Proportion of samples >1 NTU.

[d] Standard pH units.

* *p* < .05,

** *p* < .001,

*** *p* < .0001.

TABLE 4

Microbial and Chemical Contaminants in Surface Water Collected May to July 2009 in a Community Bordering a Regional Landfill

Contaminant	**Surface Water**		
	#	**# Pos**[a]	**Mean (Min, Max)**[b]
Turbidity (NTU)	50	50	202 (5.6, 1358)
Fecal coliforms (MPN/100 mL)[c]	40	40	1480 (13, >2420)
E. coli (MPN/100 mL)[d]	50	21	535 (0.5, >2420)
Enterococci (MPN/100 mL)[e]	50	43	759 (2, >2420)
Nitrate (ppm)	40	40	0.21 (0, 2.75)
Ammonia (ppm)	40	40	0.35 (0, 1.42)
pH[f]	40	–	5.9 (4.7, 7.9)
Aluminum	40	2	5035 (770, 9300)
Arsenic	40	11	2.9 (0.3, 6)
Barium	40	11	113.8 (20.4, 710)
Cadmium	8	8	0.3 (0.3, 0.3)
Chlorine (ppm)	40	39	4.7 (0, 14.5)
Chromium	40	10	5.1 (0.3, 23)
Copper	40	12	16.5 (15, 21)
Iron (ppm)	40	40	6.9 (0.9, 20.5)
Lead	40	10	5.4 (1.3, 15)
Manganese (ppm)	40	40	0.7 (0.03, 2.0)
Nickel	40	2	14 (12, 16)
Selenium	8	8	0.4 (0.3, 1.0)
Silver	8	8	0.3 (0.3, 0.3)
Zinc	40	40	20.3 (17, 27)
Total alkalinity $CaCO_3$ (ppm)	40	40	54.6 (5, 155)
Total organic carbon (mg/L)	51	51	19 (2.5, 83)
Bromodichloromethane	40	4	0.4 (0.3, 0.6)
Bromomethane	40	1	0.36
Chloroform	40	4	2.2 (1.6, 2.6)
Chloromethane	40	7	0.3 (0.2, 0.4)
Isopropylalcohol	40	1	0.9
Naphthalene	40	3	0.5 (0.4, 0.8)
p-Isopropyltoluene	40	3	0.5 (0.2, 1.1)
Toluene	40	10	0.6 (0.3, 2.1)

Note. NTU = nephelometric turbidity units; MPN = most probable number; ppm = parts per million; $CaCO_3$ = calcium carbonate.

[a] Number of samples above the detection threshold unless otherwise noted.

[b] Units are µg/L unless otherwise noted.

[c] Proportion of samples >200 MPN/100 mL.

[d] Proportion of samples >33 MPN/100 mL.

[e] Proportion of samples above 125 MPN/100 mL.

[f] Standard pH units.

TABLE 5

Relation of Distance From Landfill With Concentrations of Water Quality Indicators in Surface Water Collected in a Community Bordering a Regional Landfill From May to July 2009

Indicator	**# Samples**	**Mean (*SD*)**	**β coefficient**[a]	**95% *CI***
Enterococci (MPN/100 mL)	50	759 (952)	−600.0	−1106, −93
E. coli (MPN/100 mL)	50	535 (892)	−418.0	−889, 52
Fecal coliforms (MPN/100 mL)	40	1480 (1050)	−213.0	−814, 388
Turbidity (NTU)	50	202 (289)	−85	−237, 68
Total organic carbon (mg/L)	50	19.3 (13.5)	−1.8	−7.8, 4.3

Note. SD = standard deviation; *CI* = confidence interval; MPN = most probable number; NTU = nephelometric turbidity units.

[a] The beta coefficient is the change in the concentration of the water quality indicator for every 100-m increase in distance from the landfill, derived from conditional fixed effects linear regression models.